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Competitiveness and hemodynamic reactions to competition

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Abstract

This study examines the effects of competition and competitiveness on hemodynamics. Cardiovascular activity was measured in 27 men at resting baseline and during a car racing game, which comprised a solo race against time and three races against an experimenter. To assess hematocrit, blood was collected at rest and after the final race. Trait competitiveness was assessed by questionnaire. Competition elicited increases in hematocrit, blood pressure, heart rate, and total peripheral resistance, as well as decreases in preejection period and heart rate variability. The final race was rated as more competitive than the solo race. Compared to intrapersonal solo racing, the final interpersonal race was associated with shorter preejection periods and faster heart rates, markers of beta-adrenergic activation. Although trait competitiveness was not associated with beta-adrenergic activation, variations in state competitiveness were.

Descriptors: Cardiovascular reactivity, Competition, Competitiveness, Hemoconcentration.

Acute psychological stress perturbs the cardiovascular system (Obrist, 1981; Turner, 1994; Turner, Sherwood, & Light, 1992), and it has been proposed that exaggerated cardiovascular reactions to psychological stress contribute to the pathogenesis of cardiovascular disease (Manuck, 1994; Matthews et al., 1986). Given that competition has been construed as an acute stress (Harkins, Kamerling, & Church, 1992; Jones & Hardy, 1990; McKay, Selig, Carlson, & Morris, 1997), it is surprising that we know so little about the cardiovascular impact of competition, particularly interpersonal sports competition. Based on social evaluation theory (Festinger, 1954), Martens (1976) has defined competition as “a process in which the comparison of an individual’s performance is made with some standard in the presence of at least one other person who is aware of the criterion for comparison and can evaluate the comparison process” (p. 14).

The few naturalistic and laboratory studies of interpersonal competition have restricted their measurement of cardiovascular activity to blood pressure and/or heart rate (Diamond et al., 1984; Felsten, 1995; Glass et al., 1980; Holt-Lunstad, Clayton, & Uchino, 2001; McKay et al., 1997). As yet, only two studies have used impedance cardiography, in addition to sphygmomanometry, to provide a comprehensive account of the cardiovascular adjust-

ments to competition. Sherwood, Light, and Blumenthal (1989) tested participants in pairs using a competitive reaction time task. As well as increases in blood pressure and heart rate, Sherwood et al. observed marked shortening of the preejection period, which, under conditions of stable posture and physical activity, is inversely related to myocardial contractility and regarded as a sensitive index of beta-adrenergic influences on the heart. However, reaction time tasks are undoubtedly a poor laboratory analogue of most sporting competitions. In a more recent study in our laboratory (Harrison et al., 2001), cardiovascular reactions were measured to a car racing game, undertaken in competition or in cooperation with an experimenter, or individually. In contrast to cooperation, competition provoked increases in blood pressure and heart rate, and a shortening of preejection period, that were greater during interpersonal than intrapersonal competition.

Even less attention has been paid to the cardiovascular consequences of individual differences in trait competitiveness during competition. Martens (1976) has defined competitiveness as “a disposition to strive for satisfaction when making comparisons with some standard of excellence in the presence of evaluative others” (p. 3). From Martens’ perspective, competition will engage individuals to the extent that they are high in competitiveness. Consequently, the effects of competition on psychophysiological activity should be related to individual differences in dispositional competitiveness. There is evidence that individuals classified as Type A, who characteristically display high levels of competitiveness, show greater heart rate and blood pressure reactions in challenging and competitive settings than those classified as Type B (Dembroski, MacDougall, Herd, & Shields, 1979; Diamond et al.,

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1984; Glass et al., 1980; Jennings, 1984; Shahidi, Henley, Willocks, & Furnham, 1991; Van Egeren, 1979). However, it is not clear which components of Type A behavior drive these effects, given that Type A can embrace time urgency, hostility, and job involvement, as well as competitiveness. Further, it is important to recognize that competitiveness is almost certainly domain specific, that is, those who are highly competitive in sports or games may be not at all competitive in an academic or a job context (Weinberg & Gould, 1995). This implies that measures of competitiveness within a particular domain, such sports and games, will predict responses to competition within that domain more than generic measures of competitiveness.

Using a sports-specific measure of competitiveness, the Sport Orientation Questionnaire (Gill & Deeter, 1988), Harrison et al. (2001) found that both competitiveness and the desire to win were associated with reductions in preejction period and increases in blood pressure to competition. This suggests that sympathetic activation during competition is especially characteristic of those with high levels of sports competitive drive. In apparent contrast, but in line with expectations from the arguments expounded above, Öhman, Nordby, and Svebak (1989) found no association between competitiveness and cardiovascular reactions to a video car racing game. The measure of competitiveness in their study, however, was general, that is, the hard-driving and competitive subscale of the Jenkins Activity Survey (Jenkins, Zyzanski, & Rosenman, 1979), rather than sports and games specific. It is also worth noting that the competition task used by Öhman et al. was intrapersonal rather than interpersonal.

The present study examined the impact of competition and trait competitiveness on hemodynamic activity. Based on Martens' (1975) social evaluation approach to competition, intrapersonal and interpersonal *objective competitive situations* were created in which progressively higher standards were set by increasing the demands of the tasks combined with increases in the rewards for winning and the punishments for failing. This was expected to produce a progressively increasing *subjective competitive situation* due to progressively increasing motivation to compete. The subjective competitive situation should also be influenced by individual differences in dispositional competitiveness (Martens, 1975). It was hypothesized that competition, particularly highly demanding and motivating interpersonal competition, would elicit beta-adrenergic cardiovascular activation. Further, the cardiovascular effects of competition were expected to be most pronounced in individuals high in competitiveness. However, associations between cardiovascular reactivity and competitiveness were expected to be restricted to a sports-specific measure of competitiveness.

As another important extension of Harrison et al. (2001), the current study also investigated the effect of competition on blood composition. Cardiovascular disease, particularly its acute expression in myocardial infarction and stroke, has been linked to changes in blood composition as well as flow (for review, see Allen & Patterson, 1995). Blood composition is perturbed by laboratory stress tasks. For example, Patterson and his associates (Patterson, Krantz, & Jochum, 1995; Patterson, Marsland, Manuck, Kameleva, & Muldoon, 1998) have observed increases in hematocrit, the percentage of red blood cells in the blood, and decreases in plasma volume during mental arithmetic and speech tasks. The effects of competition and competitiveness on rheological measures such as hematocrit have yet to be examined. It was also hypothesized that competition would produce hemoconcentration, and that the increase in hematocrit would be most pronounced in individuals high in dispositional sports-related competitiveness.

Thus, the present study revisited the issue of the cardiovascular effects of competition and competitiveness, using a task protocol that varied in competitive demand and allowed comparison of intrapersonal and interpersonal competition, assessing both sports-specific and generic competitiveness, and extending measurement to include an index of blood composition.

Methods

Participants

Twenty-seven undergraduate and postgraduate men with a mean age of 21.59 ($SD = 3.30$) years, mean height of 1.81 ($SD = 0.08$) m, and mean weight of 78.72 ($SD = 10.14$) kg participated. None smoked, had a history of cardiovascular disease, or were currently taking medication. Participants were asked to abstain from vigorous exercise and alcohol for 24 hr, and from food and caffeine for 1 hr, prior to testing. All participants gave informed consent and the study was approved by the local ethics committee.

Competition Task

Following a 20-min rest period, participants undertook a 12-min competition task using a nationally popular motorized racing car game (Scalextric, Hornby Hobbies Ltd.). The 543-cm racing track was arranged as a figure-eight circuit. Two electrically controlled cars traveled separately along two parallel lanes of the track. A trigger on a handset controlled the car speed. As the trigger was operated by the index finger of the participant's dominant hand, limited muscle activity was needed to control the car. Immediately prior to the competition task, participants refamiliarized themselves with the demands of the racing car game for 1 min. It should be noted that all participants were already well acquainted with the game. Competition consisted of four 3-min sequential races. At the end of each race, the cars were quickly (<10 s) repositioned on the track for the following race, which then started immediately. Performance-dependent points could be earned during each race. Participants were informed that the individual who achieved the most points would win a £25 voucher. A scoreboard with the points of the best five participants, which was updated as necessary, was displayed on the laboratory wall.

During the first race of the competition, the participant competed on his own against time (solo race). In the first, second, and third minutes of this race, 100 points were gained for any lap faster than 4.5, 3.5, and 2.5 s, respectively. The numbers of participants meeting these lap time criteria were 27 (100%), 10 (37%), and 0 (0%), respectively. In the second and third minutes, an extra 50 points were obtained for completing more than 10 and 15 laps, respectively. If the participant's car left the track, it was replaced by the experimenter. Participants received feedback on lap times and the number of laps completed, as well as encouragement. In sum, the requirements of this intrapersonal task increased progressively to make the third minute the most demanding.

Following the solo race, the participant competed in three 3-min races against an experimenter. In the first dual race, the participant started one lap ahead of the experimenter. If the participant was ahead at the end of the 3 min, he was awarded 100 points for winning. Every time the participant's car derailed, five points were deducted. If either of the cars derailed, the competing experimenter replaced it on the track, and the race recommenced only when both cars were on the track. A countdown to the end of each race was indicated by the noncompeting experimenter announcing when there were 60 s, 30 s, and 10 s to go. In the second dual race, the participant started one half lap ahead of the exper-

imeter. A win was now worth 200 points, with 10 points deducted for each derailment. In the third dual race, the participant and the experimenter started level. It was emphasized that this was the most important race, and the reward for winning was 500 points, although the penalty for each derailment was 20 points. Throughout all four races, a noncompeting experimenter encouraged the participant to win as many points as possible, and, in the dual races, to beat the competing experimenter. The competing experimenter was a highly practiced expert, who used the faster of the two seemingly identical cars and the most advantageous lane, and was able, in all cases, to control the course of the race and ensure that the races always had a close finish. In the first and second dual races, where the participants were given head starts, the experimenter gradually ate away the lead, and when level, tried to keep the cars close, letting the participant win where realistically possible (93% of the participants won each of these races). In the final race, although trying to keep the cars as close as possible for much of the race, the experimenter now attempted to win the close finish; this critical race was won by only 44% of participants. Thus, the requirements of the interpersonal tasks increased progressively in order to make the final dual race the most demanding, with the final minute of this race being the culmination of the interpersonal competition. The mean (*SD*) number of points scored in the four races were 177.78 (56.04), 58.52 (30.09), 121.48 (61.56), and 97.41 (279.00), respectively, and the corresponding numbers of derailments in the dual races were 6.74 (2.01), 6.37 (2.44), and 6.70 (2.45).

Questionnaires and Task Ratings

At the beginning of the initial rest period, participants completed the 25-item Sports Orientation Questionnaire (SOQ; Gill & Deeter, 1988) and the 20-item Competitiveness Index (CI; Smither & Houston, 1992). The Competitiveness (13 items, measuring enjoyment of competition and desire to strive for success in competitive sport settings), Win Orientation (6 items, measuring focus on interpersonal comparison and winning in competition), and Goal Orientation (6 items, measuring focus on personal performance standards) subscales of the SOQ have good psychometric properties, with internal consistencies, as measured by Cronbach's α s, of .95, .86, and .86, and test-retest reliability coefficients of .89, .82, and .73, respectively (Gill & Deeter, 1988). In the SOQ, respondents are directed explicitly to describe reactions to sport situations, and the questions concern sports competition. Examples from the Competitiveness subscale include "my goal is to be the best athlete ever," "I work hard to be successful in sports," and "I look forward to the opportunity to test my skills in competition." Response options for each item varied from A (*strongly agree*) to E (*strongly disagree*). The CI is directed more towards competitiveness in everyday social settings, with questions like "I would like to be on a debating team," "I try to avoid arguments," and "I get satisfaction from competing with others." Response options for each item were yes or no. Internal consistency of this questionnaire is high, with a Cronbach's α equal to .90 (Smither & Houston, 1992).

At the end of competition, participants rated on 7-point Likert scales (0 = *not at all*; 6 = *extremely*) how competitive, engaging, difficult, and exciting they had found each of the four races.

Cardiovascular Measures

An oscillometric blood pressure monitor (Critikon, Dinamap) and a brachial cuff, placed on the nondominant arm, were used to measure systolic (SBP), mean arterial (MAP), and diastolic (DBP)

blood pressure. Blood pressure was measured every 3 min during the task and rest periods. Indices of cardiodynamic activity were recorded continuously using electrocardiography (ECG) and impedance cardiography (ICG), in accordance with published guidelines (Sherwood et al., 1990). The ECG was recorded using a Morgan 509 Cardiac Monitor and three disposable pregelled Ag/AgCl spot electrodes (Invisatrace, ConMed Corporation) positioned in a modified chest configuration; the two active electrodes were placed on the right collar bone and a rib on the left side beneath the heart, and the ground electrode was sited on a rib at the right side of the body. The ICG was recorded using a Minnesota Impedance Cardiograph (Model 304B) and four circumferential mylar band electrodes (Instrumentation for Medicine, Inc.) placed around the neck and thorax. The ECG and dZ/dt signals were recorded at 500 Hz, and Z_0 was sampled at 250 Hz. Both signals were checked on a beat-to-beat basis using an interactive scoring program (Kelsey & Guethlein, 1990). Sixty-second ensemble averages of the ECG and ICG recordings provided the following measures: heart rate (HR, in beats per minute); prejection period (PEP, in milliseconds); stroke volume (SV, in milliliters), using the Kubicek formula (Kubicek et al., 1974) and dZ/dt_{\max} calculated relative to the B-wave; cardiac output (CO, in liters per min), and total peripheral resistance (TPR, in units of dyne-s/cm^{-5}).

The square root of the mean of the sum of the squared successive differences in cardiac interbeat intervals (IBIs), a measure of heart rate variability (HRV), was calculated from the beat-to-beat data of each 60-s epoch, using the formula, $\text{RMSSD} = \sqrt{1/n \sum (IBI_i - IBI_{i-1})^2}$, where i = current IBI, and n = number of IBIs in the epoch (Ewing, Borsey, Bellavere, & Clarke, 1981; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

A 75- μL blood sample was taken from the left ear lobe using a lancet (Steriseal) at the end of rest and competition. Blood was collected in a Na-heparin micro hematocrit tube (Scientific Laboratory Supplies Ltd.), and stored at 4°C in a refrigerator. Following completion of testing, samples were centrifuged for 5 min at 11,096 rev/min (Micro Haematocrit Mk IV, Hawksley & Sons Ltd.). After spinning, the hematocrit was measured using a rotary reader.

Procedure

Participants completed a single 90-min laboratory session that started at either 9:30 a.m. or 1:00 p.m. On arrival at the laboratory, the procedure was explained, demographic information collected, and the electrodes and brachial cuff attached. Participants were then seated in a comfortable armchair, and remained seated for the remainder of the session. An initial blood pressure measure was taken to familiarize participants with cuff inflation and deflation. Following instruction and instrumentation (30 min), they then completed a period of formal rest. During this 20-min rest period, blood pressure measurements were initiated at the start of min 11, 14, 17, and 20. ICG and ECG were recorded from min 9 to 20. At the end of the rest, a blood sample was taken. In the competition task, blood pressure measurements were initiated at the beginning of min 3, 6, 9, and 12, that is, in the last minute of each race. ICG and ECG were recorded continuously during competition. Immediately after the final race, a second blood sample was taken.

Data Reduction and Analysis

The self-report ratings were subjected to a series of four race (solo race, first dual race, second dual race, third dual race) repeated

measures multivariate analyses of variance (MANOVAs). For each MANOVA, the corrected degrees of freedom, a measure of effect size (η^2), and where appropriate, Newman-Keuls post hoc comparisons were reported.

Analysis of the cardiovascular data was confined to those minutes when blood pressure was measured. To determine whether resting cardiovascular activity was stable, separate four 1-min (11, 14, 17, 20) MANOVAs were performed on the data from the initial rest period. Significant effects emerged for HR, $F(3,24) = 3.06$, $p < .05$, $\eta^2 = .277$, and SBP, $F(3,24) = 3.11$, $p < .05$, $\eta^2 = .280$. HR was marginally slower and SBP higher during the first measure ($M = 65.85$ bpm; $M = 117.52$ mmHg) than during the subsequent three measurements ($M_s = 67.08$, 66.65 , and 67.90 bpm; $M_s = 115.89$, 115.26 , and 115.74 mmHg), which did not differ from one another. With these minor exceptions, resting hemodynamic activity was stable over time. Accordingly, the four measurements were averaged to provide a rest value for each variable. Each cardiovascular variable was then analyzed using a three condition (rest, solo race, third dual race) MANOVA.

Cardiovascular reactivity for the solo and final dual races was calculated as the difference between the value for each of these races and the rest value. To examine the relationships between the psychological measures of competitiveness and cardiovascular reactions to the solo race and the final dual race, median splits were performed separately on each of the four questionnaire measures (SOQ subscales and CI) to create high and low groups. A series of 2 Group (high, low) \times 2 Condition (solo race, final dual race) ANOVAs were conducted on the reactivity scores (i.e., race value minus rest value) for each cardiovascular variable. Similar 2 Group \times 2 Condition analyses were conducted on the ratings of competitiveness. Finally, Pearson product-moment correlation coefficients were computed to determine whether cardiovascular reactivity was related to task rating scores.

A 5% significance level was adopted for all analyses. Due to occasional missing data, the number of participants included in each analysis varied, and this is reflected in occasional variations in the reported degrees of freedom.

Results

Task Ratings

The ratings associated with each race are presented in Table 1. Separate four condition (solo race, first dual race, second dual race, third dual race) MANOVAs revealed significant effects for

Table 1. Mean (SD) Ratings for Each Race of the Competition Task

Rating	Solo race	First dual race	Second dual race	Third dual race
Competitive	3.22 (1.60)	4.41 (1.31) ^a	4.81 (1.04) ^a	5.52 (0.89) ^{a,b,c}
Engaging	4.55 (0.80)	4.59 (0.97)	4.81 (0.96)	5.22 (0.93) ^{a,b,c}
Difficult	3.81 (1.30)	3.78 (1.48)	4.22 (1.25) ^a	4.81 (1.49) ^{a,b,c}
Exciting	3.93 (1.44)	4.37 (1.24) ^a	4.93 (1.07) ^{a,b}	5.26 (1.02) ^{a,b}

Note. Ratings were made on 7-point scales (0 = not at all, 6 = extremely).

^aSignificantly different at $p < .05$ from solo race. ^bSignificantly different at $p < .05$ from first dual race. ^cSignificantly different at $p < .05$ from second dual race.

competitiveness, $F(3,24) = 30.41$, $p < .001$, $\eta^2 = .792$, engagement, $F(3,24) = 5.53$, $p < .005$, $\eta^2 = .409$, difficulty, $F(3,24) = 5.66$, $p < .005$, $\eta^2 = .414$, and excitement, $F(3,24) = 8.74$, $p < .001$, $\eta^2 = .522$. Post hoc analyses indicated that participants found the final dual race significantly more competitive, engaging, and difficult than the three previous races, as well as being more exciting than the solo race and the first dual race. The second dual race was rated as more competitive, difficult, and exciting than the solo race, as well as more exciting than the first dual race. Finally, the first dual race was considered to be more competitive and exciting than the solo race.

Effects of Competition on Cardiovascular Activity

Analyses focused on the solo race and the final dual race, because these were, respectively, the least and most competitive. Figure 1 shows the cardiovascular activity during rest and these two races. Separate MANOVAs (rest, solo race, third dual race) yielded significant condition effects for TPR, $F(2,22) = 3.81$, $p < .05$, $\eta^2 = .257$, DBP, $F(2,22) = 29.81$, $p < .001$, $\eta^2 = .730$, MAP, $F(2,22) = 32.72$, $p < .001$, $\eta^2 = .748$, SBP, $F(2,22) = 26.35$, $p < .001$, $\eta^2 = .705$, HR, $F(2,25) = 24.39$, $p < .001$, $\eta^2 = .661$, PEP, $F(2,25) = 20.56$, $p < .001$, $\eta^2 = .622$, and HRV, $F(2,23) = 4.69$, $p < .05$, $\eta^2 = .290$, but not for CO, $F(2,25) = 1.55$, $p = .23$, $\eta^2 = .110$. Post hoc analyses revealed that TPR, DBP, and MAP (i.e., indices of vascular activity) were higher during both races than during rest. In terms of indices of beta-adrenergic cardiac activity during competition, PEP shortened whereas SBP and HR increased from rest to the solo race, and from the solo race to the final dual race. CO, however, did not vary significantly among conditions. HRV, the measure of cardiac vagal tone, was lower during the two races than during rest. Finally, a two condition (rest, competition) repeated measures ANOVA revealed that hematocrit increased from rest ($M = 45.81$, $SD = 2.54\%$) to competition ($M = 46.81$, $SD = 2.82\%$), $F(1,23) = 10.22$, $p < .005$, $\eta^2 = .308$.

Cardiovascular Reliability

Pearson correlation analyses were computed separately for both the absolute levels and the reactivity scores of each cardiovascular variable during the solo task and the final dual race. As shown in Table 2, individual differences in both cardiovascular activity and cardiovascular reactivity were highly consistent across the races.

Competitiveness and Cardiovascular Reactivity

The mean (SD) scores were 53.07 (6.08), 21.78 (3.89), and 24.74 (2.97) for the Competitiveness, Win Orientation, and Goal Orientation subscales of the SOQ, and that for the Competitiveness Index was 15.00 (2.92). Correlational analyses indicated that the Competitiveness subscale and the Competitiveness Index were significantly related, $r(25) = .66$, $p < .001$, and that each correlated significantly with Win Orientation, $r(25) = .59$, $p < .001$, and, $r(25) = .46$, $p < .05$, respectively.

Separate 2 Group (high, low) \times 2 Condition (solo race, final dual race) ANOVAs conducted on the reactivity scores yielded few significant main or interaction effects for group. However, there were two significant group main effects for TPR reactions, $F(1,22) = 4.49$, $p < .05$, $\eta^2 = .170$, and CO reactions, $F(1,25) = 5.54$, $p < .05$, $\eta^2 = .181$, to the races, based on the median split of SOQ Competitiveness subscale scores. The high competitiveness group ($M_{\text{Reactivity}} = 222.76$, $SD = 237.98$ dyne-s/cm⁻⁵) displayed greater increases in TPR than the low competitiveness group ($M_{\text{Reactivity}} = 16.15$, $SD = 237.97$ dyne-s/cm⁻⁵), whereas the low group

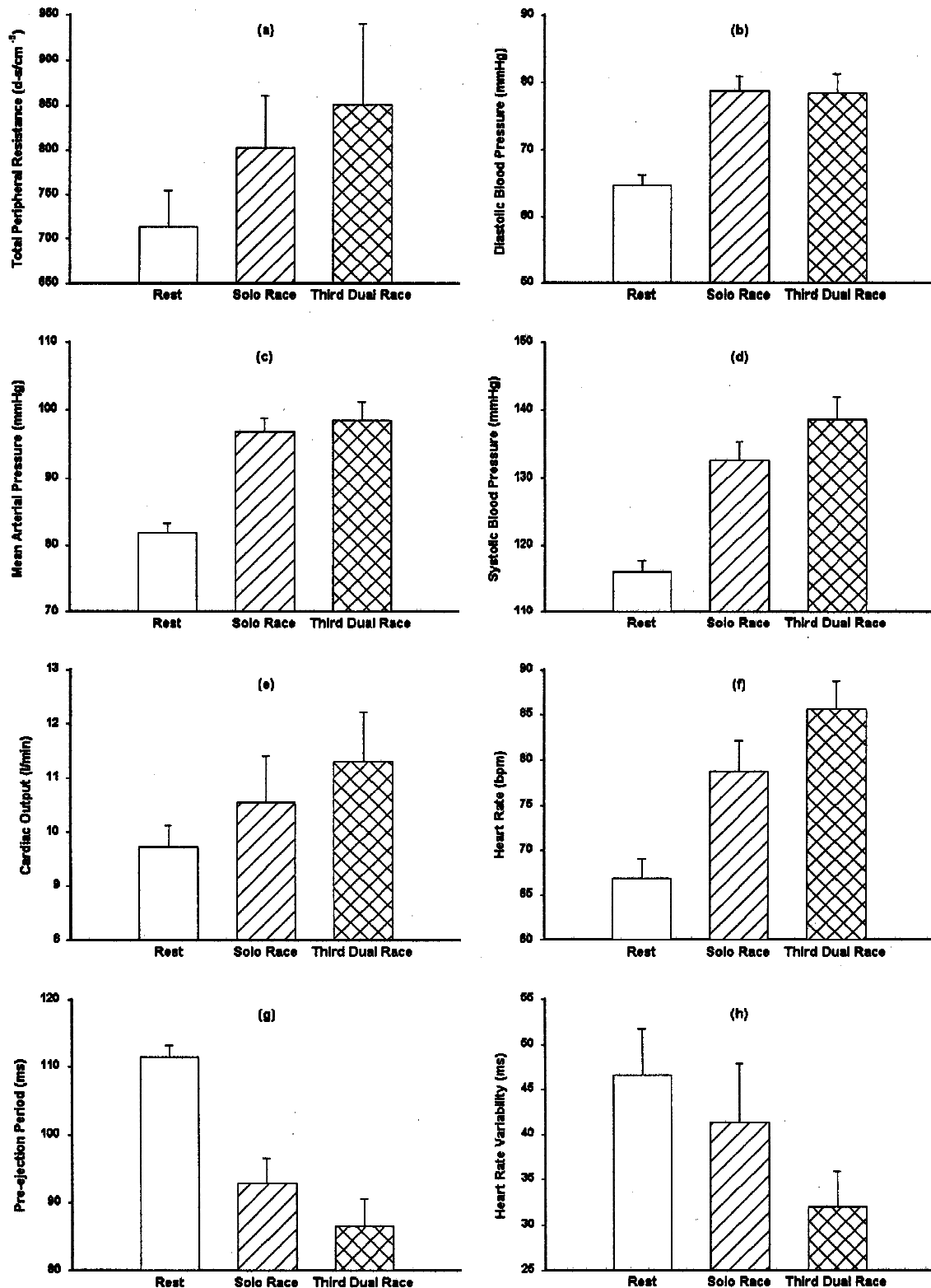


Figure 1. Mean (*SE*) cardiovascular activity at rest, during the solo race, and during the final dual race: TPR (a), DBP (b), MAP (c), SBP (d), CO (e), HR (f), PEP (g), and HRV (h).

($M_{\text{Reactivity}} = 3.04$, $SD = 3.91$ l/min) exhibited greater CO reactions than the high group ($M_{\text{Reactivity}} = -0.51$, $SD = 3.91$ l/min). In addition, two group ANOVAs revealed that hematocrit reactivity was not related to dispositional competitiveness.

Task Ratings and Cardiovascular Reactivity

Task ratings were not significantly correlated with cardiovascular reactions. However, the change in the ratings of competitiveness (final dual race value – solo race value) was significantly corre-

Table 2. Pearson Correlation Coefficients Computed for Levels (Activity) and Change Scores (Reactivity) for each Cardiovascular Variable between the Solo Race and the Final Dual Race

Variable	Cardiovascular activity	Cardiovascular reactivity
TPR	.82***	.71***
DBP	.80***	.74***
MAP	.87***	.82***
SBP	.83***	.73***
CO	.79***	.78***
HR	.77***	.62***
PEP	.72***	.69***
HRV	.41*	.51**

*Significant at $p < .05$; **significant at $p < .01$; ***significant at $p < .001$.

lated with the corresponding changes in reactivity for both PEP, $r(25) = -.41$, $p < .05$, and HR, $r(25) = .40$, $p < .05$. Thus, increases in rated competitiveness from the intrapersonal to the final interpersonal competition were associated with increases in beta-adrenergic activation.

State and Trait Competitiveness

Participants high in dispositional competitiveness tended to rate the final dual race as more competitive than those low in competitiveness, although the difference was only statistically significant for those high and low on the Competitiveness subscale of the SOQ, $F(1,25) = 4.79$, $p < .05$, $\eta^2 = .161$. The mean (*SD*) competitiveness ratings for these high and low competitiveness groups were 5.86 (0.36) and 5.15 (1.14), respectively. No such effect emerged for the solo race.

Discussion

There was a progressive increase from the solo race to the third dual race in participants' self-reports of how competitive, engaging, difficult, and exciting they found the races. In particular, the final dual race was judged as more competitive than the solo race, confirming that the manipulation to increase standards of objective competition produced the expected differences in the subjective competitiveness of the situations (Martens, 1975). This was paralleled by the magnitude of the cardiovascular perturbations observed. PEP shortened from rest to the intrapersonal solo competition, and exhibited a further reduction in magnitude during the final interpersonal competition. Similar effects emerged for SBP and HR, which increased from rest to the solo race and increased further during the third dual race. These interracial differences appeared despite the lack of counterbalancing and the resultant likely temporal adaptation effects (Kelsey et al., 1999). The other cardiovascular variables, with the exception of CO, showed overall changes from rest to competition, but did not vary between the intrapersonal and interpersonal competition conditions. The overall pattern of effects for competition is indicative of increased beta-adrenergic activation of the heart (shortening of PEP, and, to a lesser extent, increases in HR and SBP), increased alpha-adrenergic activation of the vasculature (increases in TPR and DBP), and some vagal withdrawal (decrease in HRV). This pattern

of effects in response to competition is similar to that found by Harrison et al. (2001). That interpersonal competition provoked greater beta-adrenergic activity than intrapersonal competition and the finding that increases in rated competitiveness from the intrapersonal to the final interpersonal competition were associated with changes in PEP and HR reactivity suggest that beta-adrenergic activation may provide a sensitive response marker of variations in the subjective competitiveness of situations (Martens, 1975).

It is possible that factors other than competition per se and differences in the competitiveness of the intrapersonal and interpersonal races could underlie the effects observed. For example, the final interpersonal competition was regarded as more difficult than the intrapersonal condition, and task difficulty has been found to influence cardiovascular reactions to laboratory stress (Carroll, Turner, & Hellawell, 1986; Carroll, Turner, & Prasad, 1986; Light & Obrist, 1983). In addition, the interpersonal race contained a greater element of social evaluation, which has also been reported to increase cardiovascular reactions to laboratory stress (Kelsey et al., 2000; Kors, Linden, & Gerin, 1997; Lepore, Allen, & Evans, 1993; Smith, Nealey, Kircher, & Limon, 1997). However, it is almost certainly impossible to disentangle variations in objective competitive demands from variations in task difficulty, and competition is inevitably bound up with social comparison and evaluation (Martens, 1975). Although participants remained seated throughout, the physical demands of the task were minimal, and ostensibly the same in the intrapersonal and interpersonal races, variations in beta-adrenergic cardiac activation could reflect subtle variations in energy expenditure between conditions. Our data do not allow us to discount these various alternative explanations.

Turning now to individual differences in sports-specific and general competitiveness, there were few significant associations between cardiovascular reactivity and the SOQ and CI questionnaire measures. Further, given the number of tests of difference computed, care should be exercised in interpreting the few significant effects that emerged. Nevertheless, individuals high in sports-specific competitiveness showed greater vascular reactions to both intrapersonal and interpersonal competition than those low in this trait. In line with the hypothesis that dispositional competitiveness is domain specific, no such effects were found for general competitiveness. Thus, although competition was characterized by increased beta-adrenergic activation, those with higher sports-specific competitive dispositions appeared to exhibit greater increases in alpha-adrenergic drive. This result is in apparent contrast to the findings of Harrison et al. (2001) in which competitiveness, again measured by the SOQ, was significantly correlated with PEP and SBP reactions to interpersonal competition. Nevertheless, consistent with the present study, Harrison et al. also observed a positive association between competitiveness and a marker of vascular reactivity, DBP reactions to competition. Further, the current study found that individuals high in sports-specific competitiveness rated the final dual race as more competitive than those low in competitiveness, and as indicated, the change in rated competitiveness between races was associated with changes in PEP and HR reactivity. Thus, although trait competitiveness was not related to beta-adrenergic activation, variations in state competitiveness were.

Given the time course of blood composition measures such as hematocrit (Patterson et al., 1995), comparison was restricted to rest and overall competition. Nevertheless, it is clear that competition not only perturbs cardiovascular activity but also affects blood composition. However, contrary to our hypothesis, changes

in hematocrit were not associated with dispositional competitiveness. The finding that hematocrit increased with competition is in line with the findings of others using noncompetitive laboratory stress tasks (Patterson et al., 1995, 1998). To explore the mechanisms underlying the hemoconcentration elicited by competition, correlational analyses were performed between the change in hematocrit (task value – rest value) and cardiovascular reactivity scores. These analyses revealed that Δ hematocrit was significantly correlated with Δ PEP, $r(22) = -.40$, $p = .05$, Δ HR, $r(22) = .48$, $p < .05$, and Δ SBP, $r(21) = .41$, $p = .05$, to the final dual race. Similar effects were found for cardiovascular reactivity during the solo race, which is to be expected given the stability of cardiovascular reactivity across the two races (see Table 2). Accordingly, competition-induced hemoconcentration would appear to be mediated by increases in sympathetic activation, as has been reported for other noncompetitive psychological stress tasks (Patterson et al., 1998). Thus, the hemodynamic data lend support to the proposition

that competition shows many of the characteristics of acute psychological stress.

In sum, our data suggest that beta-adrenergic activity, as indexed by PEP, may provide a response marker of the individual's evaluation of the competitiveness of situations, as it is sensitive to variations in the objective demands posed by different competitions, as well as to changes in ratings of state competitiveness. Martens (1975) has identified motivation as another factor influencing the social evaluative process during competition. Accordingly, it is reasonable to speculate that individual differences in motivational orientation towards competition might further influence beta-adrenergic activation. Developments in achievement goal theory (see, e.g., Duda & Hall, 2001) have identified specific motivational orientations in competitive settings. Future research concerned with the hemodynamic correlates of competition and competitiveness would do well to extend assessment to such individual differences in motivational orientation.

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